

M6 Working Group - High Intensity Proton Sources
(<http://www-bd.fnal.gov/icfa/snowmass/>)

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Executive Summary

The US high-energy physics program needs an intense proton source (a 1-4 MW Proton Driver) by the end of this decade. This machine will serve multiple purposes: (i) a stand-alone facility that will provide neutrino superbeams and other high intensity secondary beams such as kaons, muons, neutrons, and anti-protons (cf. E1 and E5 group reports); (ii) the first stage of a neutrino factory (cf. M1 group report); (iii) a high brightness source for a VLHC (cf. M4 group report).

Based on present accelerator technology and project construction experience, it is both feasible and cost-effective to construct a 1-4 MW Proton Driver. There are two PD design studies, one at FNAL and the other at the BNL. Both are designed for 1 MW proton beams at a cost of about US\$200M (excluding contingency and overhead) and upgradeable to 4 MW. An international collaboration between FNAL, BNL and KEK on high intensity proton facilities addresses a number of key design issues. The sc cavity, cryogenics, and RF controls developed for the SNS can be directly adopted to save R&D efforts, cost, and schedule. PD studies are also actively pursued at Europe and Japan.

There are no showstoppers towards the construction of such a high intensity facility. Key research and development items are listed below ({} indicates present status). Category A indicates items that are not only needed for future machines but also useful for the improvement of existing machine performance; category B indicates items crucial for future machines and/or currently underway.

- 1) H⁻ source: Development goals - current 60–70 mA {35 mA}, duty cycle 6–12% {6%}, emittance 0.2π mm-mrad rms normalized, lifetime > 2 months {20 days}. (A)
- 2) LEBT chopper: To achieve rise time < 10 ns {50 ns}. (B)
- 3) Study of 4-rod RFQ at 400 MHz, 100 mA, 99% efficiency, HOM suppressed. (B)
- 4) MEBT chopper: To achieve rise time < 2 ns {10 ns}. (B)
- 5) Chopped beam dump: To perform material study & engineering design for dumped beam power > 10 kW. (A)
- 6) Funneling: To perform (i) one-leg experiment at the RAL by 2006 with goal one-leg current 57 mA; (ii) deflector cavity design for CONCERT. (all B)
- 7) Linac RF control: To develop (i) high performance HV modulator for long pulsed (>1ms) and CW operation; (ii) high efficiency RF sources (IOT, multi-beam klystron). (all A)
- 8) Linac sc RF control: Goal - to achieve control of RF phase error < 0.5° and amplitude error < 0.5% {presently 1°, 1% for warm linac}. (i) To investigate the choice of RF source (number of cavity per RF source, use of high-power source); (A) (ii) to perform redundancy study for high reliability; (B) (iii) to develop high performance RF control (feedback and feedforward) during normal operation, tuning phases and off-normal operation (missing cavity), including piezo-electric fast feedforward. (A)
- 9) Space charge: (i) Comparison of simulation code ORBIT with machine data at FNAL Booster and BNL Booster; (ii) to perform 3D ring code bench marking including machine errors, impedance, and space charge (ORNL, BNL, SciDAC, PPPL). (all A)
- 10) Linac diagnostics: To develop (i) non-invasive (laser wire, ionization, fluorescent-based) beam profile measurement for H⁻; (ii) on-line measurement of beam energy and energy spread using time-of-flight method; (iii) halo monitor especially in sc environment; (iv) longitudinal bunch shape monitor. (all A)
- 11) SC RF linac: (i) High gradients for intermediate beta (0.5 – 0.8) cavity; (A) (ii) Spoke cavity for low beta (0.17 – 0.34). (B)

- 12) Transport lines: To develop (i) high efficiency collimation systems; (A) (ii) profile monitor and halo measurement; (A) (iii) energy stabilization by HEBT RF cavity using feedforward to compensate phase-jitter. (B)
- 13) Halo: (i) To continue LEDA experiment on linac halo and comparison with simulation; (ii) to start halo measurement in rings and comparison with simulation. (all B)
- 14) Ring lattice: To study higher order dependence of transition energy on momentum spread and tune spread, including space charge effects. (B)
- 15) Injection and extraction: (i) Development of improved foil (lifetime, efficiency, support); (A) (ii) experiment on the dependence of H^0 excited states lifetime on magnetic field and beam energy; (B) (iii) efficiency of slow extraction systems. (A)
- 16) Electron cloud: (i) Measurements and simulations of the electron cloud generation (comparison of the measurements at CERN and SLAC on the interaction of few eV electrons with accelerator surfaces, investigation of angular dependence of SEY, machine and beam parameter dependence); (A) (ii) determination of electron density in the beam by measuring the tune shift along the bunch train; (A) (iii) theory for bunched beam instability that reliably predicts instability thresholds and growth rates; (A) (iv) investigation of surface treatment and conditioning; (A) (v) study of fast, wide-band, active damping system at the frequency range of 50–800 MHz. (B)
- 17) Ring beam loss, collimation, protection: (i) Code benchmarking & validation (STRUCT, K2, ORBIT); (A) (ii) engineering design of collimator and beam dump; (A) (iii) experimental study of the efficiency of beam-in-gap cleaning; (A) (iv) bent crystal collimator experiment in the RHIC; (B) (v) collimation with resonance extraction. (B)
- 18) Ring diagnostics: (i) Whole area of diagnosing beam parameters during multi-turn injection; (ii) circulating beam profile monitor over large dynamic range with turn-by-turn speed; (iii) fast, accurate non-invasive tune measurement. (all A)
- 19) Ring RF: To develop (i) low frequency (~ 5 MHz), high gradient (~ 1 MV/m) burst mode RF systems; (B) (ii) high gradient (50-100 kV/m), low frequency (several MHz) RF system with 50-60% duty cycle; (B) (iii) high-voltage (>100 kV) barrier bucket system; (B) (iv) transient beam loading compensation systems (e.g. for low-Q MA cavity). (A)
- 20) Ring magnets: (i) To develop stranded conductor coil; (ii) to study voltage-to-ground electrical insulation; (iii) to study dipole/quadrupole tracking error correction. (all B)
- 21) Ring power supplies: To develop (i) dual-harmonic resonant power supplies; (ii) cost effective programmable power supplies. (all B)
- 22) Kicker: (i) Development of stacked MOSFET modulator for DARHT and AHF to achieve rise/fall time <10 -20 ns; (B) (ii) impedance reduction of lumped ferrite kicker for SNS. (A)
- 23) Instability & impedance: (i) To establish approaches for improved estimates of thresholds of fast instabilities, both transverse and longitudinal (including space charge and electron cloud effects); (ii) to place currently-used models such as the broadband resonator and distributed impedance on a firmer theoretical basis; (iii) impedance measurement based on coherent tune shifts *vs.* beam intensity, and instability growth rate *vs.* chromaticity, including that for flat vacuum chambers; (iv) to develop new technology in feedback implementation. (all B)
- 24) FFAG: (i) 3-D modeling of magnetic fields and optimization of magnet profiles; (ii) wide-band RF systems; (iii) transient phase shift in high frequency RF structures; (iv) application of sc magnets. (all B)
- 25) Inductive inserts: (i) Experiments at the FNAL Booster & JHF3; (A) (ii) programmable inductive inserts; (B) (iii) development of inductive inserts which have large inductive impedance and very small resistive impedance; (B) (iv) theoretical analysis. (B)
- 26) Induction synchrotron: (i) Study of beam stability; (ii) development of high impedance, low loss magnetic cores. (all B)